



## **Drainage Solutions: Homage to the Ponds of Folly**

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**WWD “Shock and Awe” Parade**

**WWD-1: Kesterson Reservoir**

**Type: Terminal sink managed wetlands**

**Influent: ca. 300 ug/l (predominantly selenate)**

**Outcome:ca. 6% BNS embryo deformity rate; severe overall avian reproductive failure (>30%); overt adult toxicosis among American coots**



**WWD-2: Peck Ranch**

**Type: Standard Evaporation Pond System**

**Influent: ca. 750 ug/l (predominantly selenate)**

**Outcome: ca. 50% BNS embryo deformity rate; severe overall avian reproductive failure (>70%)**



**WWD-3: Britz-Deavenport**

**Type: Steep-sided Evaporation Pond System**

**Influent: ca. 65 ug/l (predominantly selenate)**

**Outcome: ca. 33% BNS embryo deformity rate**



**WWD-4: Red Rock Ranch**

**Type: IFDM Demonstration Site**

**Influent: ca. 1,600 ug/l (predominantly selenate)**

**Outcome: highly variable; ca. 60%, 5%, 0%, 100%  
BNS embryo deformity rates**



**WWD-5: Unidentified Cotton Gin**

**Type: ephemeral puddle**

**Influent: unknown degree of contamination;  
groundwater discharge of unknown purpose**

**Outcome: ca. 16% BNS embryo deformity rate**





## Comparative bioavailability of selenium to aquatic organisms after biological treatment of agricultural drainage water

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### Abstract

Selenium (Se) is naturally abundant in the soils of the western San Joaquin Valley, California, USA. Intense agricultural activity in this region requires irrigation which leaches Se into surface waters draining to the San Joaquin River. Se water contamination and subsequent accumulation in wildlife is a serious problem in the Central Valley of California, and the subject of increasingly intensive regulatory action. Algal–bacterial selenium reduction (ABSR) is a potential new treatment approach to reduce Se in agricultural drainage, and an ABSR demonstration facility was examined with respect to its Se removal efficiency and effect on Se bioavailability and bioaccumulation. Water samples were taken to study treatment effects on Se speciation. Invertebrate tissue Se concentrations in the ABSR ponds were monitored for 2 years. Laboratory-based algal bioaccumulation tests and *in situ* microcosms with a variety of invertebrates were also used to address differences in Se bioavailability before and after ABSR treatment. The ABSR system removed about 80% of the total influent Se; however, microbial and algal activity produced selenite and organic Se, the combined concentration of which increased 8-fold during treatment. As a result of the greater bioavailability of selenite and organic Se, relative to the selenate of the influent, treatment contributed to greater Se concentrations in effluent-exposed organisms. ABSR-treated water produced Se concentrations in biota 2–4 times greater than organisms exposed to untreated water. The bioavailability of Se in the treated water was 2–10 times greater than Se in the influent. The shift to more bioavailable Se forms due to biological treatment is inherent in system design, and makes it difficult to weigh the ecological benefits of a reduction in total Se loadings from a regional perspective against the greater toxicological risk to biota in the vicinity of the effluent.

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**Keywords:** Selenium; Bioavailability; Speciation

### 1. Introduction

Selenium (Se) is a semi-metallic element found naturally in high concentrations in the soils of the western San Joaquin Valley, California (Losi and Frankenberger, 1997a). Agricultural activity in

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## **Algal-Bacterial Selenium Reduction (ABSR)**

**Toxic Equivalency Calculations (based on data in Amweg et al. 2003):**

**Start w/ 392 ug/l selenate**

**End up with 48 ug/l selenate and 28 ug/l reduced Se (total Se of 76 ug/l) after ABSR including DAF and SSF.**

**Bioaccumulation:**

**Worms - start out with 25 ug/g dw; end up with 51.4 ug/g dw Se (ratio of ca. 2X).**

**Snails - start out with 17.3 ug/g dw; end up with 47.1 ug/g dw Se (ratio of ca. 2.7).**

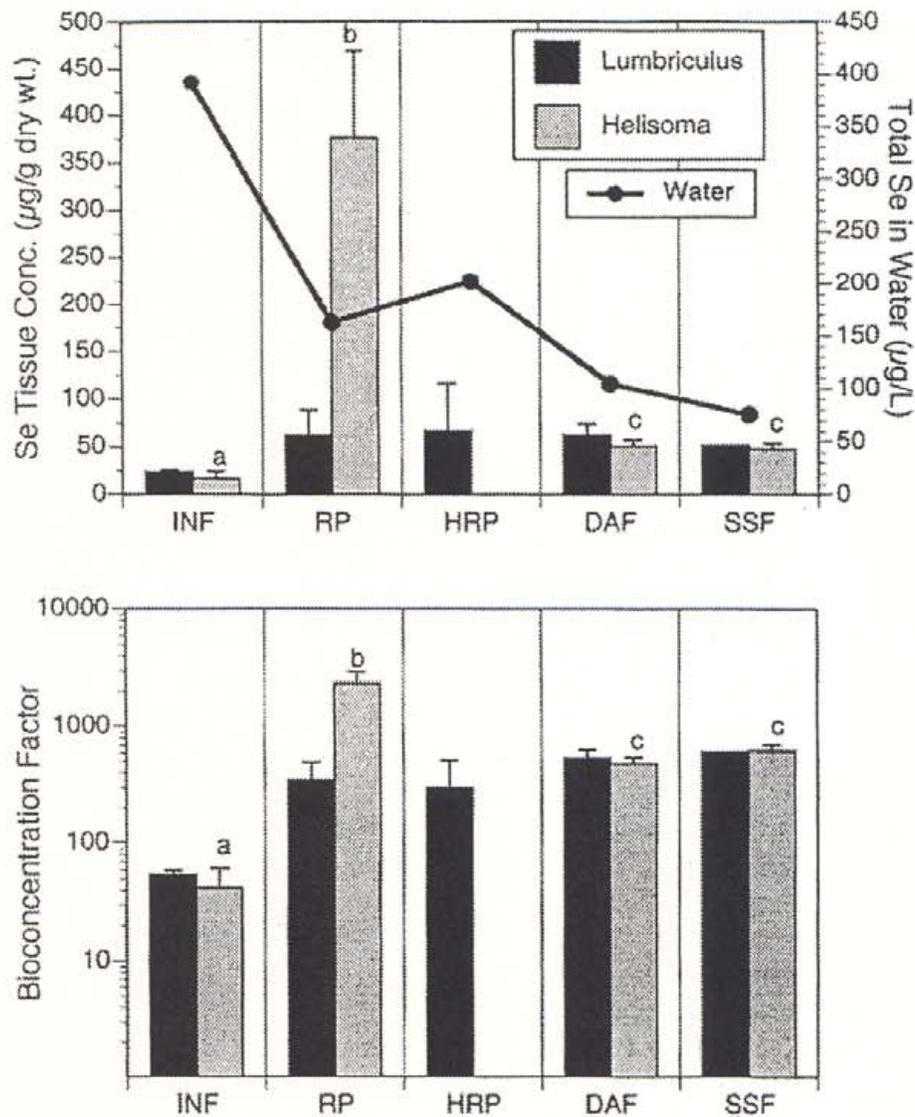
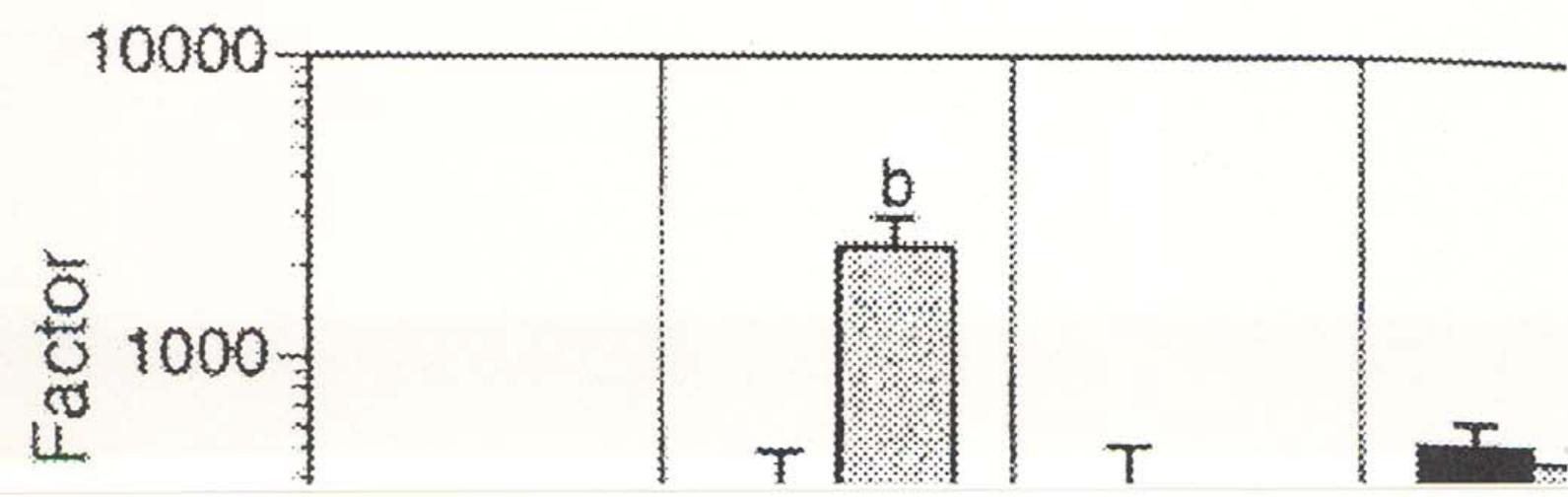
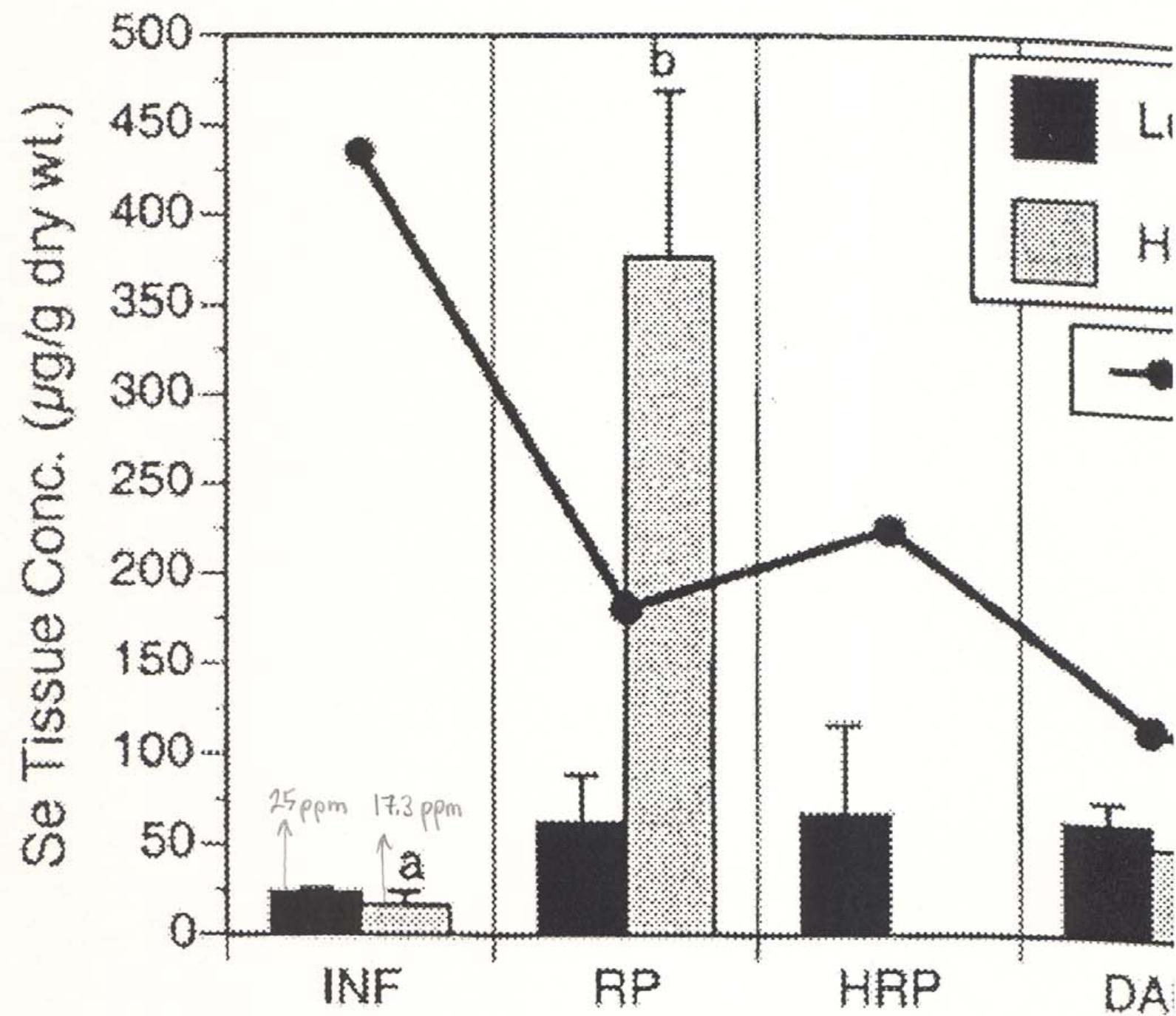


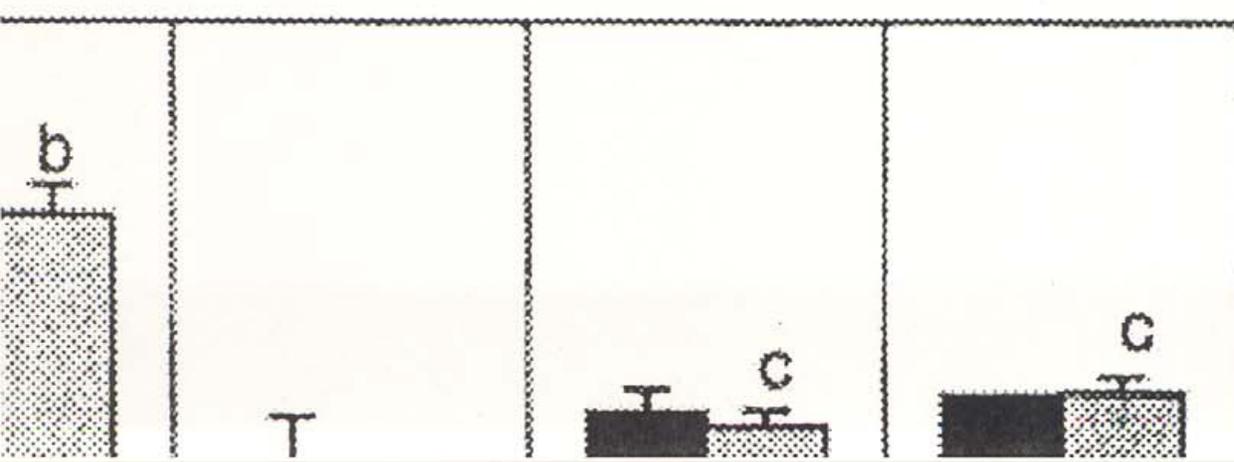
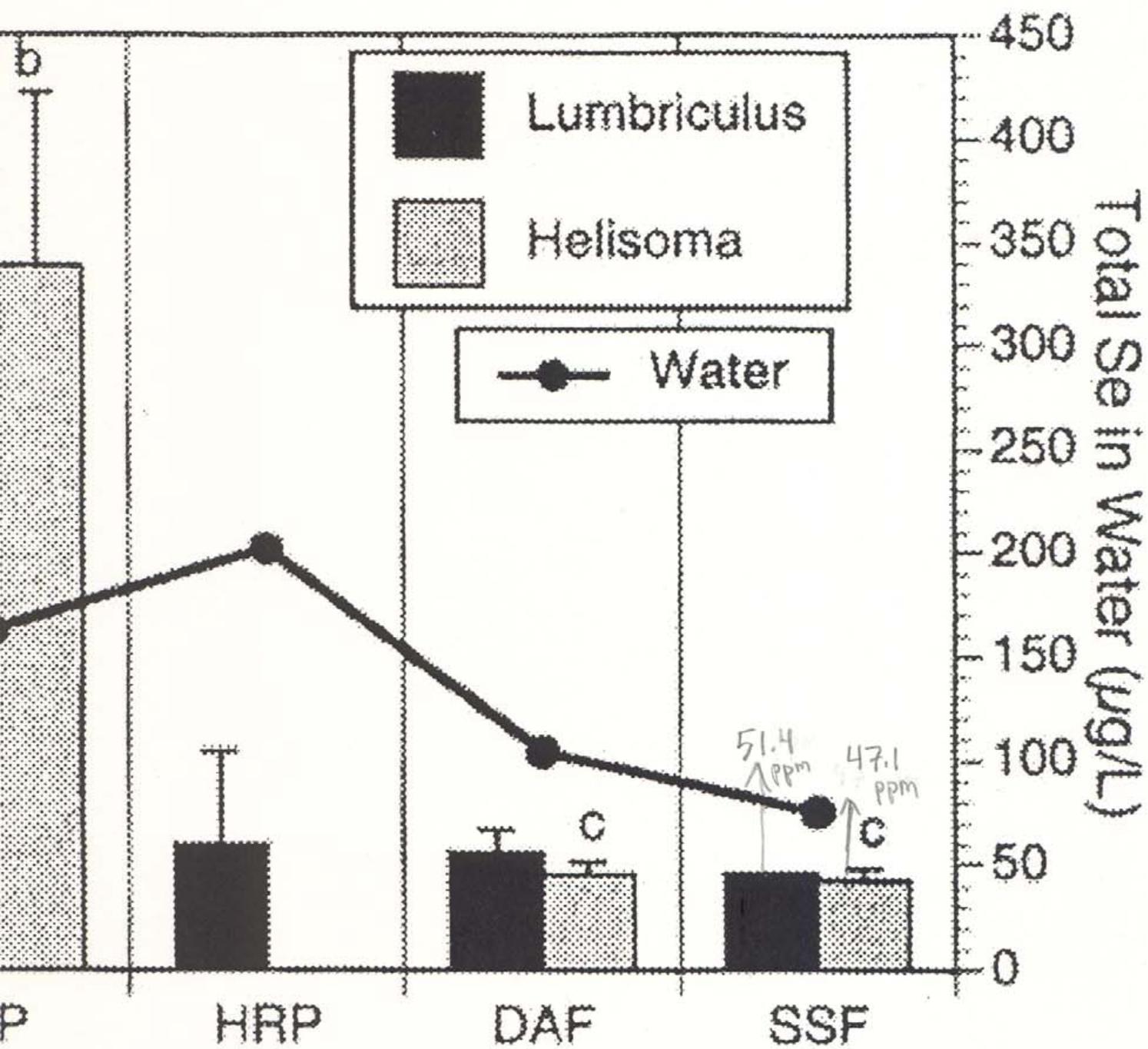
Fig. 7. Total Se concentrations and BCFs in microcosm invertebrates after 30 days in situ exposure to ABSR system water. Means and standard deviations are shown, with  $n$  usually equal to 3. Significant differences among the treatments, based on Conover's multiple comparison test ( $P < 0.05$ ) are designated by letter symbols. Average water Se concentrations at each step in the system throughout the exposure period are shown as a line in the first panel. No *Helisoma* sp. were recovered from the HRP microcosm.

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**Assuming simple linear bioaccumulation curves, the selenate toxic equivalency of ABSR product water would be 784-1,058 ug/l.**

**But curves are not linear, bioaccumulation factors are a diminishing returns function of magnitude of exposure.**

**Nonlinear curves estimated from Tulare Basin evaporation pond data for 4 taxa by CDWR in late 1980's.**

**Using log-log linear regression, BAF exponents (slopes) ranged from 0.49 - 0.62 for corixids, brine shrimp, damselflies, and midge larvae.**

**Using this range for CDWR's exponents (0.49-0.62) and constants fitted to observed results of 25 ug/g and 17.3 ug/g dw Se in worms and snails from 392 ug/l selenate water..... equations for more precisely estimating selenate toxic equivalency are derived:**

**Log (Worm Se, ppb dw) = 3.13 + 0.49 Log (water selenate equivalency, ppb)**

**Log (Worm Se, ppb dw) = 2.79 + 0.62 Log (water selenate equivalency, ppb)**

**Log (Snail Se, ppb dw) = 2.97 + 0.49 Log (water selenate equivalency, ppb)**

**Log (Snail Se, ppb dw) = 2.63 + 0.62 Log (water selenate equivalency, ppb)**

**Solving for Worm tissue of 51.4 ug/g dw = 1,870 ug/l and 1,362 ug/l**

**Solving for Snail tissue of 47.1 ug/g dw = 2,989 ug/l and 1,973 ug/l**

**Thus, the ABSR system Amweg et al. monitored took water with a selenate toxic equivalency of 392 ug/l and transformed it to water with a selenate toxic equivalency of roughly 1,400-3,000 ug/l !!**

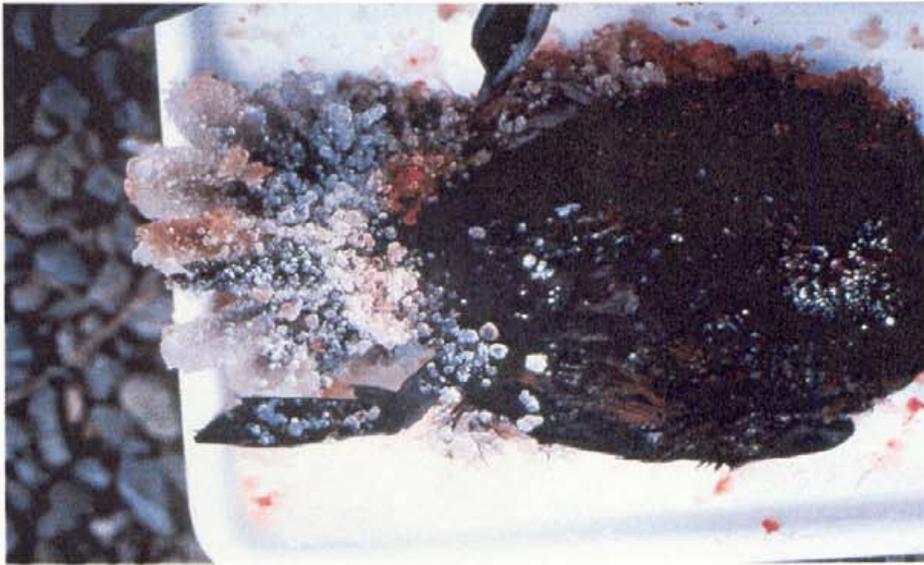
**This would have an astounding affect on amount of mitigation habitat required.**

**Can this problem be engineered out of the treatment process (a la Lundquist et al.)?**

**Amweg et al. (2003) present the pessimistic view that the problem will be resistant to re-engineering because so little form conversion is required for net increase in toxic equivalency that re-engineering performance would have to be extremely efficient at selenium removal.**

**Even assuming a treatment system has been honed at pilot scale that actually reduces toxic equivalency, instead of increasing it, reading Appendix E of SLUDFRE is sobering. There are enough critical unknowns to raise images of a certain desalination plant at Yuma, AZ!**

## **What about non-breeding birds?**



**TDS values likely to be high enough to transform the phenomenon of salt encrustation into a major issue.**

**Even with mitigated design, in 2001 ca. 3,000 acres of TLDD-H and TLDD-S attracted 7 million bird-use-days.**

**Simple extrapolation suggests SLUDFRE evap ponds would attract > 10 million bird-use-days per year.**

**What about other constituents?**

**At a minimum, Boron must be evaluated.**

**Potential for additive effects must be evaluated.**

**What about mitigation uncertainties?**



**TLDD system is a proven “egg farm”, but it is still unproven what kind of recruitment of young into adult population is being achieved? Lack habitat diversity, particularly with regard to cover, may not provide for full-cycle reproductive needs.**

**At minimum, a rigorous recruitment study needs to be conducted before SLUDFRE adopts TLDD model.**

## So where do we stand?

1. **Ocean disposal is an environmental black box. Would probably be more expensive than estimated by SLUDFRE, presuming that major research effort would have to be funded to at least partially resolve environmental unknowns.**
2. **Delta disposal is much more clearly defined environmentally (Luoma and Presser 2000; CalFed Program) ... very little wiggle room, if any.**
3. **In-Valley ponding of WWD drainwater has an absolutely brutal environmental track record, even under Se conditions similar to the best SLUDFRE scenarios (i.e., end water with <100 ug/l selenate toxic equivalency). Re-use component raises the stakes even higher for broad spectrum of contaminant concerns that may or may not be ameliorated sufficiently by treatment.**
4. **IFDM - Red Rock all over the map. Sometimes the genie stays in the bottle, sometimes it gets out. At small scale, even when the genie gets out, much less damaging than In-Valley ponding is. Unlikely to scale-up very well because it is so management intensive.**

**Any of the SLUDFRE alternatives would require enormous financial investment, near or in excess of a billion present-value dollars... just to get us through the next fifty years.**

**When added to existing water subsidies, crop subsidies, and money-lending subsidies, why are we even talking about environmental constraints?**

**Why do meetings such as this persist in assiduously avoiding the obvious economic questions? Was the Westside SJV allowed historically to become over-developed for irrigated agriculture? Is irrigation an economically inappropriate (unreasonable) land use for substantive present-day acreage (e.g., GAO 1995)?**

**Without an intellectually honest, comprehensive, economic analysis of appropriate land uses for the Westside SJV, major efforts to identify and overcome environmental constraints seem to be putting the cart before the horse.**

**For whatever the reason, the absence from SLUDFRE of a substantive land retirement alternative, likely excludes what constitutes both the economically and environmentally superior alternative (e.g., WWD webpage).**